Is The Hydrogen Highway Safe?

Carl Baust, P.E.

Fire Protection Engineer

Orange County Fire Authority

CA H2 Net Media Workshop

September 1, 2005

California State University – Los Angeles

Purpose: Highlight Safety Concerns of Hydrogen Energy

- Basic Concepts
- Safety Issues
- Public Perception

Basic Concepts

"Comparing hydrogen safety against conventional fuels yields no clear cut answers…hazards are far more influenced by circumstances than for other fuels."

1976 Stanford Research Institute Study

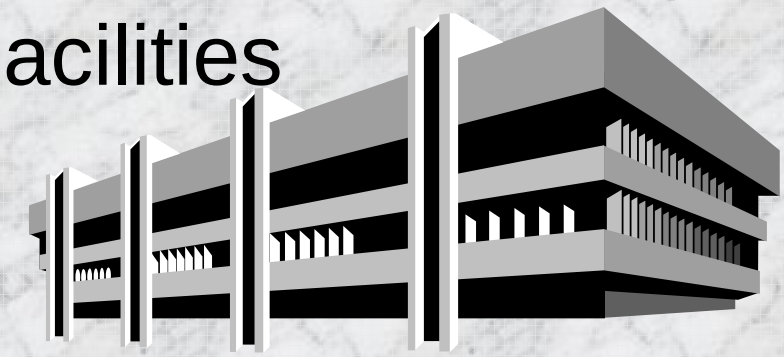
Basic Concepts

- **H2 Basics -** Wide Flammability Range, Low Ignition Energy, Burns Invisibly
  - **Energy Content: 60,958 Btu/lb (Highest)**
  - **Flammability limits (in air): 4.1 v% -74 v%**
  - **Explosion limits (in air): 18.3 v% -59 v%**
- **Today -** Mainly For Industrial Processes and Specialty Applications
- **Future -** On Site Production At Fuel Stations, Industries, and Homes

Basic Concepts

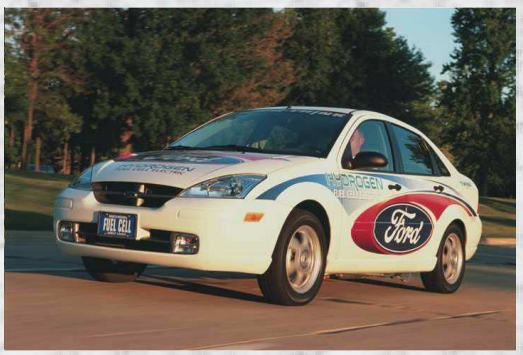
- **State Policy** - Implicit Safety Mandate

- **Existing -** Research & Development and Design Facilities



Basic Concepts

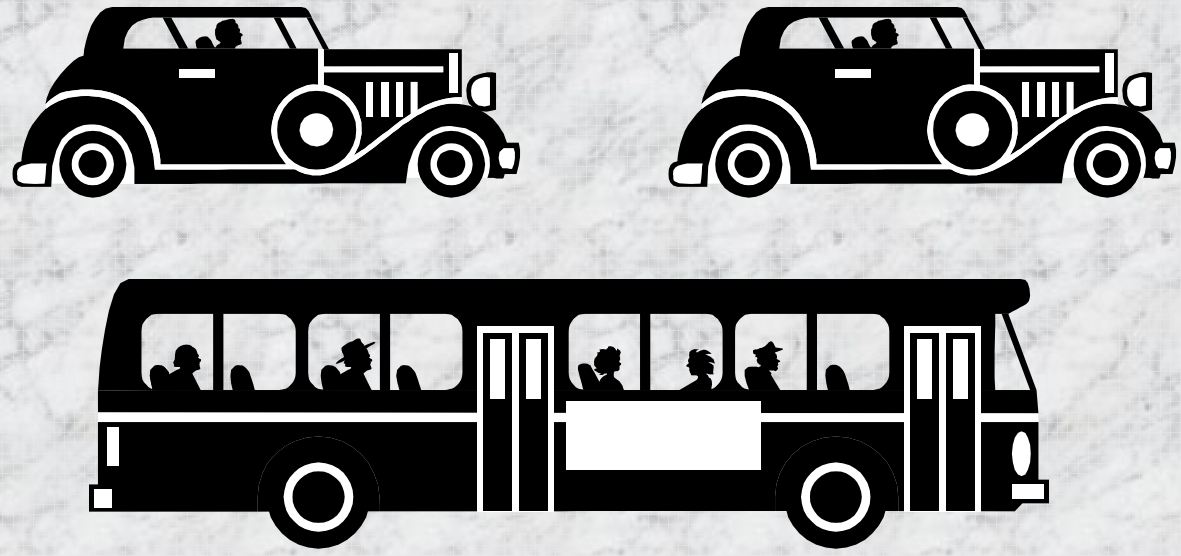
- **Fuel Cell Vehicles –** Electric Vehicles



- **Stationary Fuel Cells –** Valuable Experience

Basic Concepts

- **Large Experiment -** Nazi Germany
  (About 2,000 Vehicles)

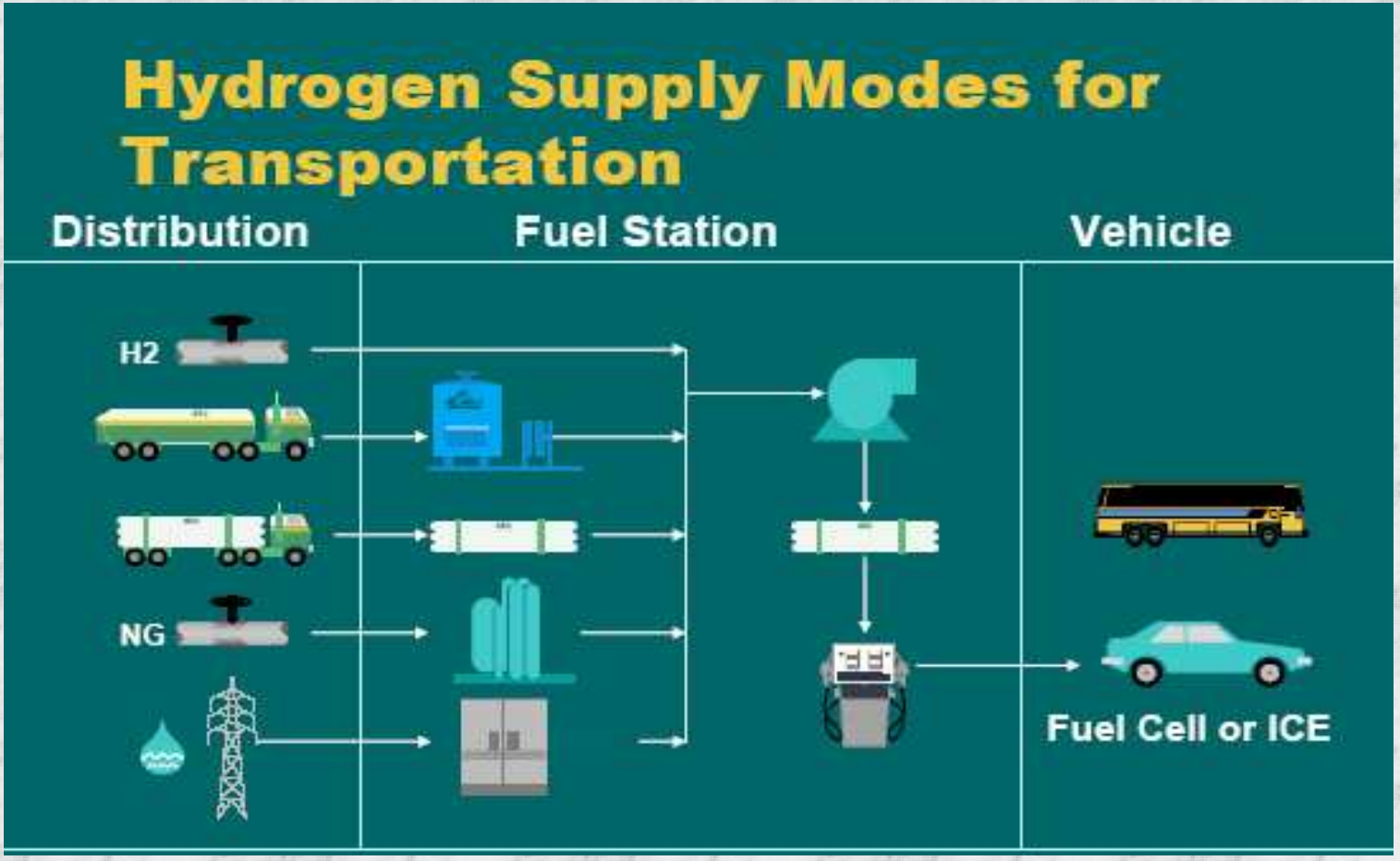


Demonstrated Commercial Viability

Basic Concepts

Property	Gasoline	Methane	Hydrogen
Flammability Limits In Air (vol	1.0 - 7.6	5.3 - 15.0	4.0 - 75.0
Ignition Energy In Air (Mj)	0.24	0.29	0.02
Ignition Temperature (°C)	228 - 471	540	585
Flame Temperature In Air (°C)	2197	1875	2045
Explosion Energy (g-TNT/kJ)	0.25	0.19	0.17
Flame Emissivity (%)	34 - 43	25 - 33	17 - 25

Basic Concepts



Safety Issues

- **Safe -** Rapid Dispersal, Water Vapor

- **"Good Gas?" -** Proven Industrial Record

Safety Issues

Combustion – Hazards

- Frequently overlooked facts
  - Ignition energy is about the same as CH_4 at $\phi = 0.35$
  - H_2 is 14.4 times lighter than Air and rises with a velocity of about 20 m/s
  - Diffusion of H_2 is 3.8 times that of CH_4
- It is very difficult to get premixed flammable mixtures
- Non-Premixed flames are critically important

Safety Issues

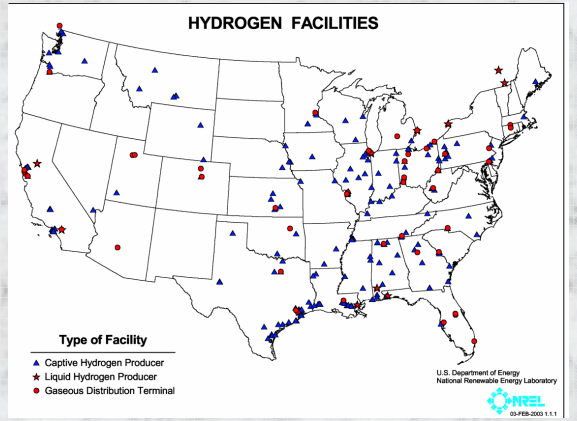
- **Vehicle Responder Training -**
  Provided By Industry

Safety Issues

- **Vehicle Responder Training -** Provided By Industry

Safety Issues

- **H2 Stations -** On or Off Site Production



H2 Plant Locations

Safety Issues

- **On Site Production** - New Equipment Listings

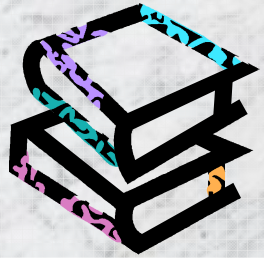
REFORMER

ELECTROLYZER

Safety Issues

- **Commercial vs. Industrial -** No Public Experience

- **Project Review -** New Regulations



Safety Issues

- **Historical** - California Fire Service

- **Expertise –** Regulators Are Challenged

“A hydrogen station! Can’t it wait until I retire?”

Safety Issues

Commercial Availability

Gasoline & Hydrogen Siting Comparison

Issue	Gasoline	Hydrogen
Time to Permit	3 months – 2 years	1 year – undefined
Zoning	Permitted / Restricted	Undefined
Design	Standard / Common Use	Custom Engr'd / One-Off
Effort to Site	.1 – .25 MY	1 – 2+ MY
NIMBY	Exception	Rule

Safety Issues

- **H2 Stations** - Varied Considerations:

  GH2? LH2? Gas Reforming?
  Electrolyzer? Delivered H2 or LH2?

Non-Standardized Designs Complicate Approvals

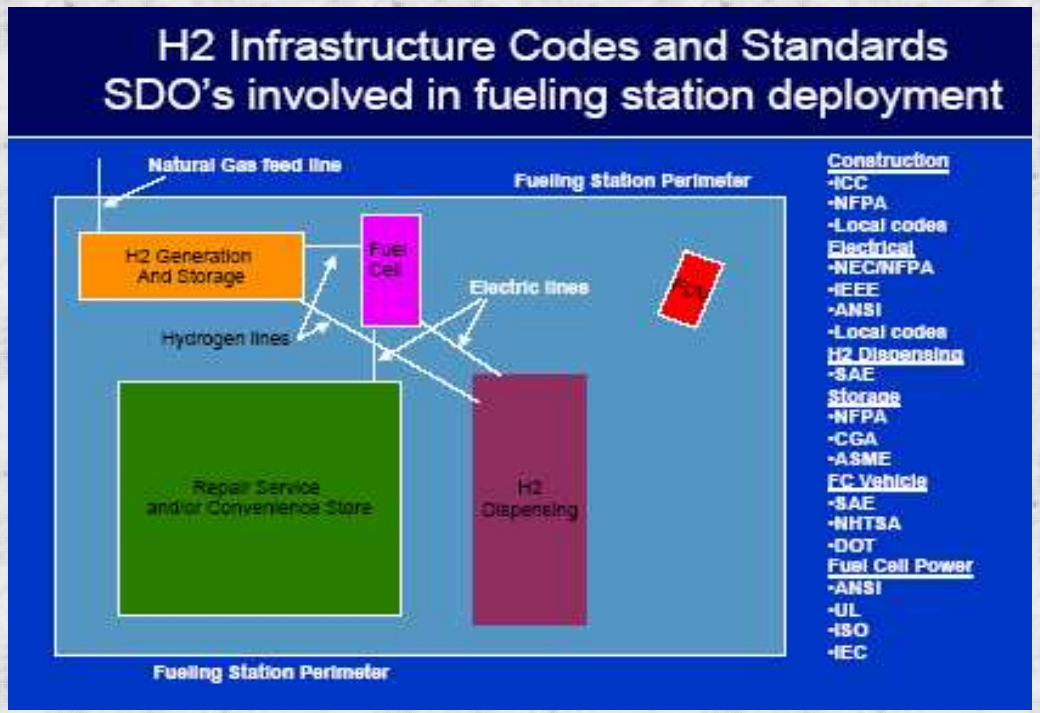
Safety Issues

- **H2 Stations -** On-Site Production

Not Simply A Dispensing Facility

Safety Issues

- **H2 Stations -** Codes & Standards



Industrial Clearances Are Difficult For H2 Stations

Safety Issues

- **H2 Vehicle Codes & Standards -**
  NFPA 52-2005 Revised For Hydrogen!!!

NFPA 52 **Vehicle Fuel Systems Code**
CSA America NGV2 **Standards for Hydrogen Vehicle Fuel Containers**
CSA America HGV 3 **Fuel System Components for Hydrogen** **Gas Powered Vehicles**
CSA America HGV 4 **Series for Fuel Dispensing** **Equipment and Components**
CSA America HPRD1 **Basic Requirements for Pressure Relief Devices for Compressed** **H2 Vehicle Fuel Containers**

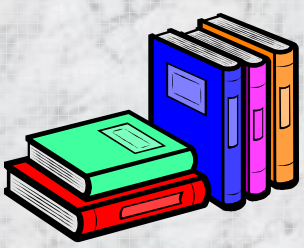
Safety Issues

H2 Fuel Station Codes & Standards

Hydrogen Transportation, Storage & Distribution
NFPA 55 Storage, Use and Handling of Compressed Gases and Cryogenic Fluids in Portable and Stationary Containers, Cylinders and Tanks.
ASME Hydrogen Standards Development Activity "piping and pipelines" "storage and transportation tanks"
ASME B31 Series Piping and Pipelines
ASME BPVC Boiler and Pressure Vessel Code
CGA Publication G5.4 Hydrogen Piping Systems at Consumer Sites

Safety Issues

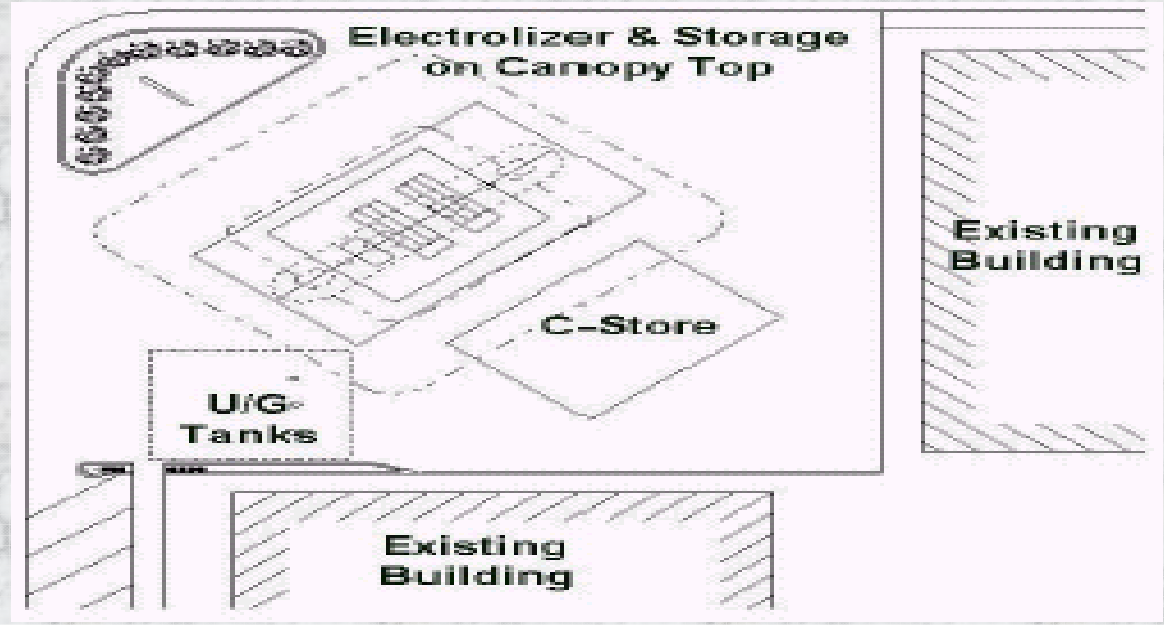
- **Presently Used Are 2001 California Building And Fire Codes**



- **Expected California Adoption Of 2003 International Codes -** Used By Almost Every State

Safety Issues

- **International Codes (2004 Revisions)**
  - Permit A Minimal Station Footprint
- Revise Storage/Equipment Locations

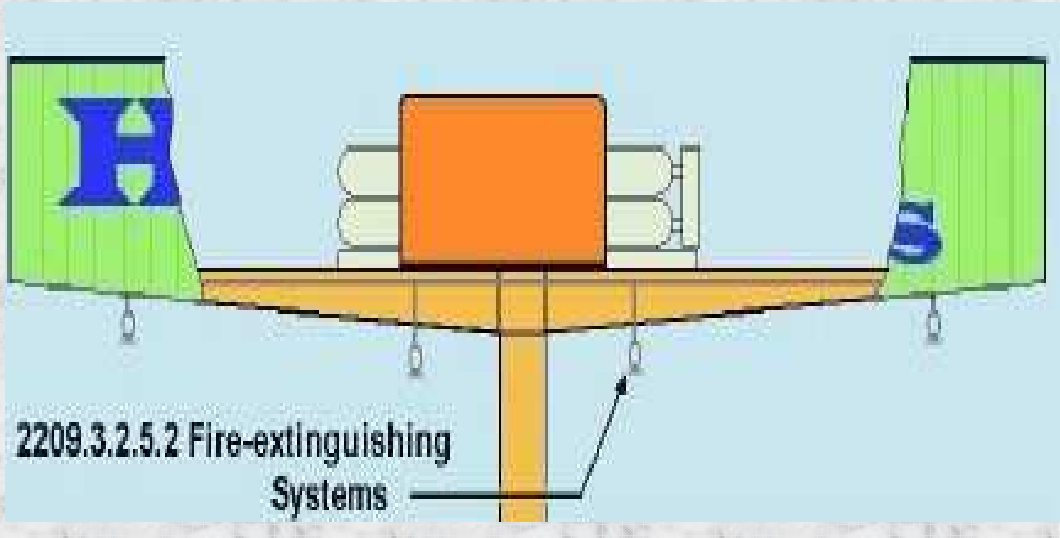


Safety Issues

- **International Codes (2004 Revisions)**
  - Permit A Minimal Station Footprint
- Underground Storage

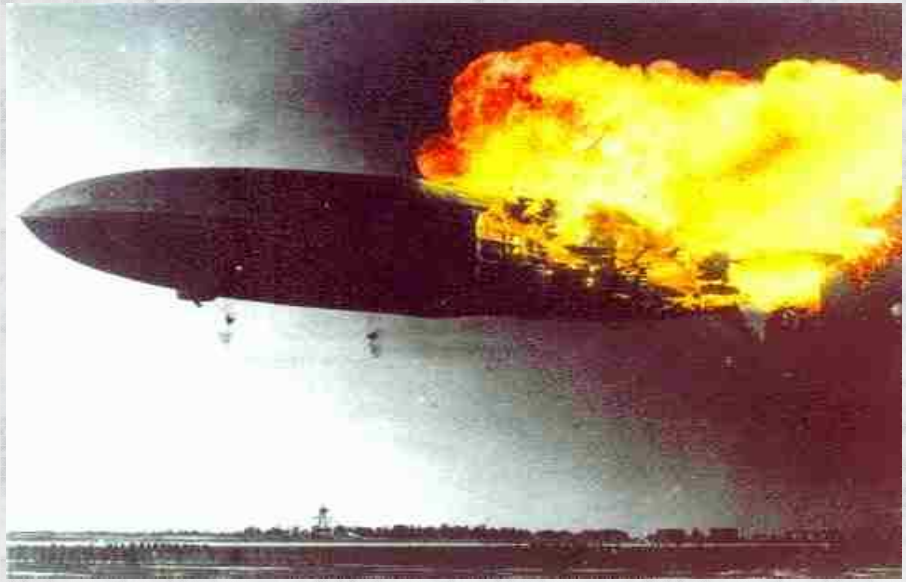
Safety Issues

- **International Codes (2004 Revisions)**
  - Permit A Minimal Station Footprint
- Canopy-top Storage Installation



Public Perception

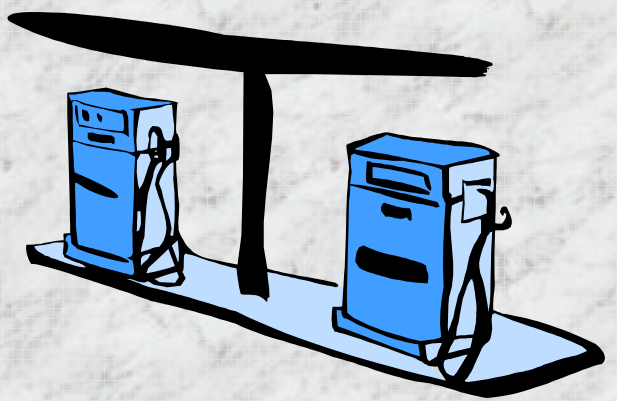
- **“Bad Gas?”-** The Hindenburg, H-Bomb



Public and <u>Professional</u> Misconceptions Are Common

Public Perception

- **Fuel Cell Vehicles -** Station Interface



Refueling Protocol Must Be Seamless

High Pressure Gas Refueling Requires Monitoring

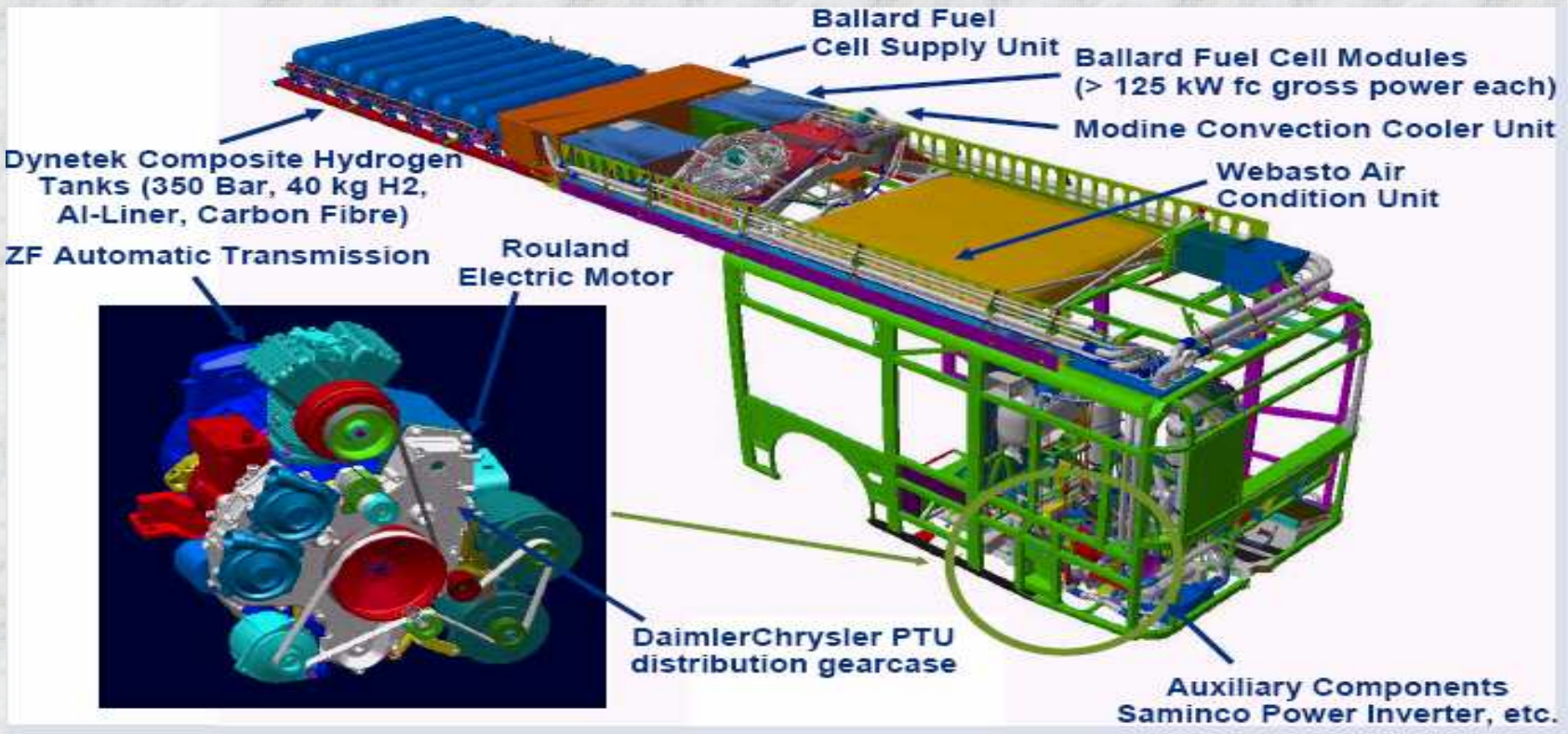
Public Perception

- **Vehicle And Stationary Storage Tank Types** (Courtesy NFCRC)

Composite	Metal Hydride	Cryogenic
		
HP GH2	LP GH2	LH2

Storage Media Exceeds Existing Crash Standards

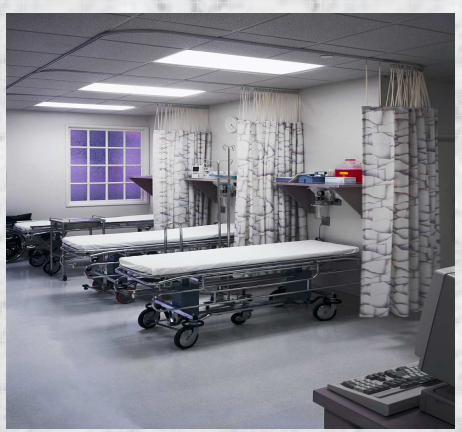
Public Perception



H2 Buses Are Similar To CNG Versions
Public Exposure Is Substantial

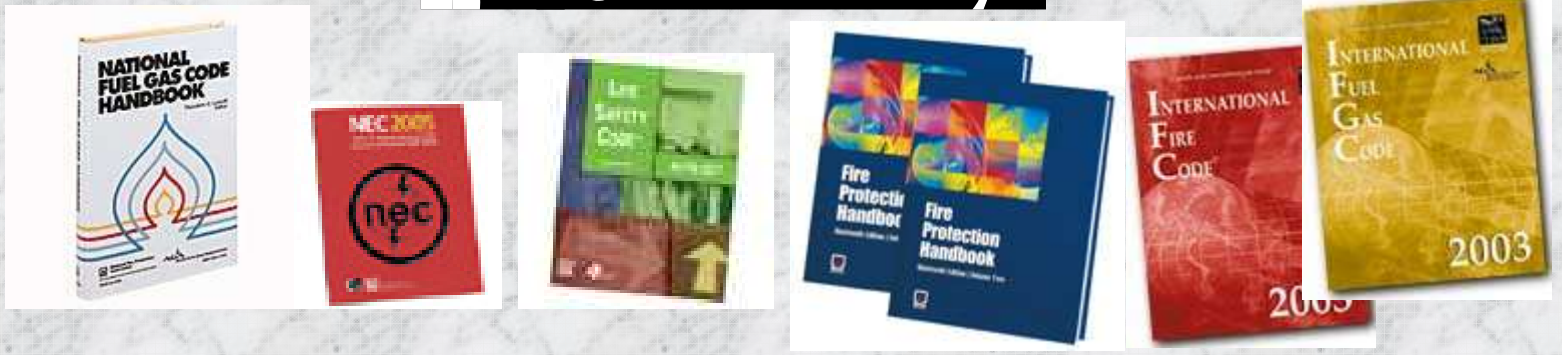
Public Perception

- **Public Reassurance –** Society Uses High Pressure Gases



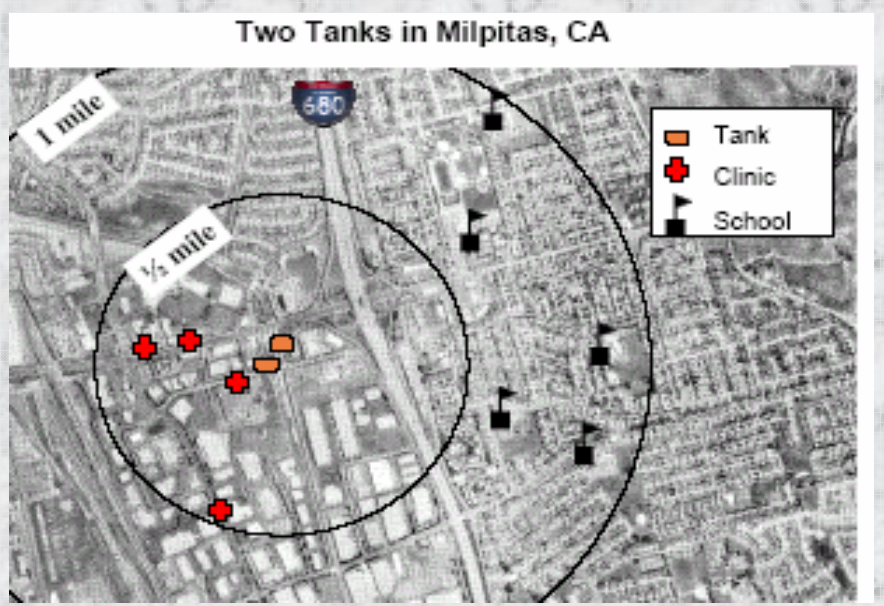
Public Perception

- **Codes –** Are Being Developed And Will Enhance Public Safety



Public Perception

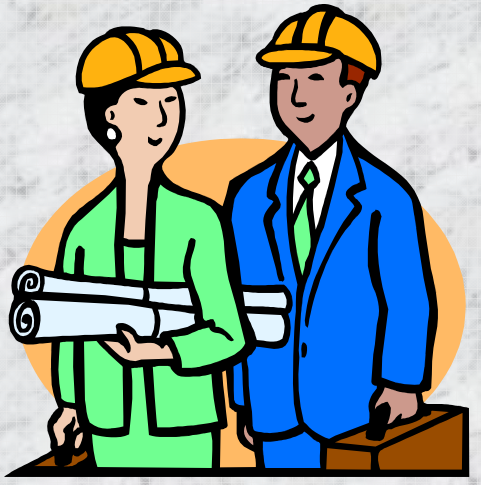
- **Gas Dispersal Models –** A Simple Tool That Can Address Concerns



"Where Will The Gas Go?"

Public Perception

- **Certifications –** Trades And Professions Must Become Expert In This Demanding Technology



5,000 PSI+ Pressures!

Public Perception

- **Approvals –** UL And Other Test Labs Have Recognition

Unlisted Equipment Is Being Addressed

Public Perception

- **H2 <u>Prototype</u> Stations –** Are Operating

No "Show Stopper" Safety Issues Have Yet Arisen

Public Perception

- **Education –** The Media Has A Critical Role

Public Perception

A New Energy Consciousness Is Coming

Public Perception

The Hydrogen Highway Leads To The Hydrogen Society

WELCOME TO THE FUTURE!

Thank You

carlbaust@ocfa.org
(714) 573-6112